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WO 96/00484 A1
Zetterberg, P et al. IEEE Transactions on Vehicular Technolo gy, vol. 44, no. 3, Aug. 1995, p.651-60 Gerlich et al. ITG-Fachberichte Conference Title ITG-Fachber . (Germany) no. 135 1995 p. 109-16

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UK CL (Edition N) **H4L LDSE LDSG LDSH LDSJ LDSL**
INT CL[6] **H04Q 7/36 7/38**
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(54) Channel Allocation in a Space Division Multiple Access Radio Communication System

(57) A communication system (10) comprises coverage areas (12-20) served by individual base stations (24-28) having adaptive arrays of antenna elements. A space division multiple access (SDMA) system is implemented by each base station, in which a specific channel (channel A, 34) is repeatedly re-used in its coverage area (12) provided that communication units (40-46) served by this specific channel are spatially resolvable by the adaptive array. In the event that the base station 24 determines that it either cannot resolve two communication devices (44, 46) from one another on a single channel, or a spatial separation between these two communication devices (44, 46) is insufficient to sustain co-channel use without adverse and detrimental effect to the integrity of both communications, the base station 24 assigns, on a dynamic basis, a different channel (channel B, 36) to each communication device of the unresolvable pair.

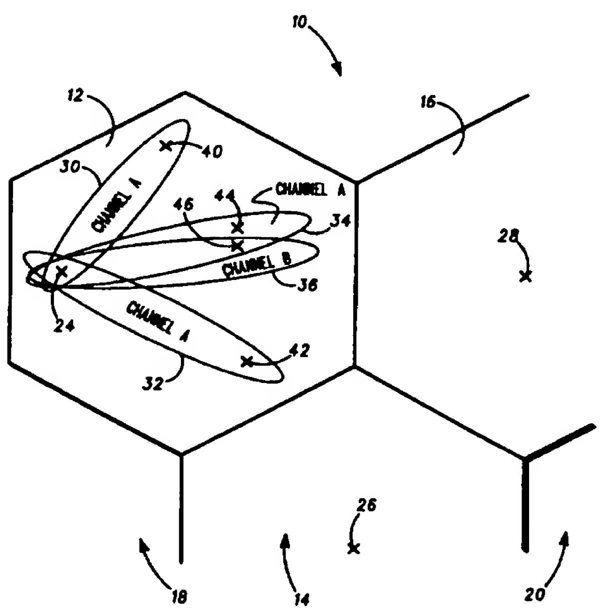

FIG.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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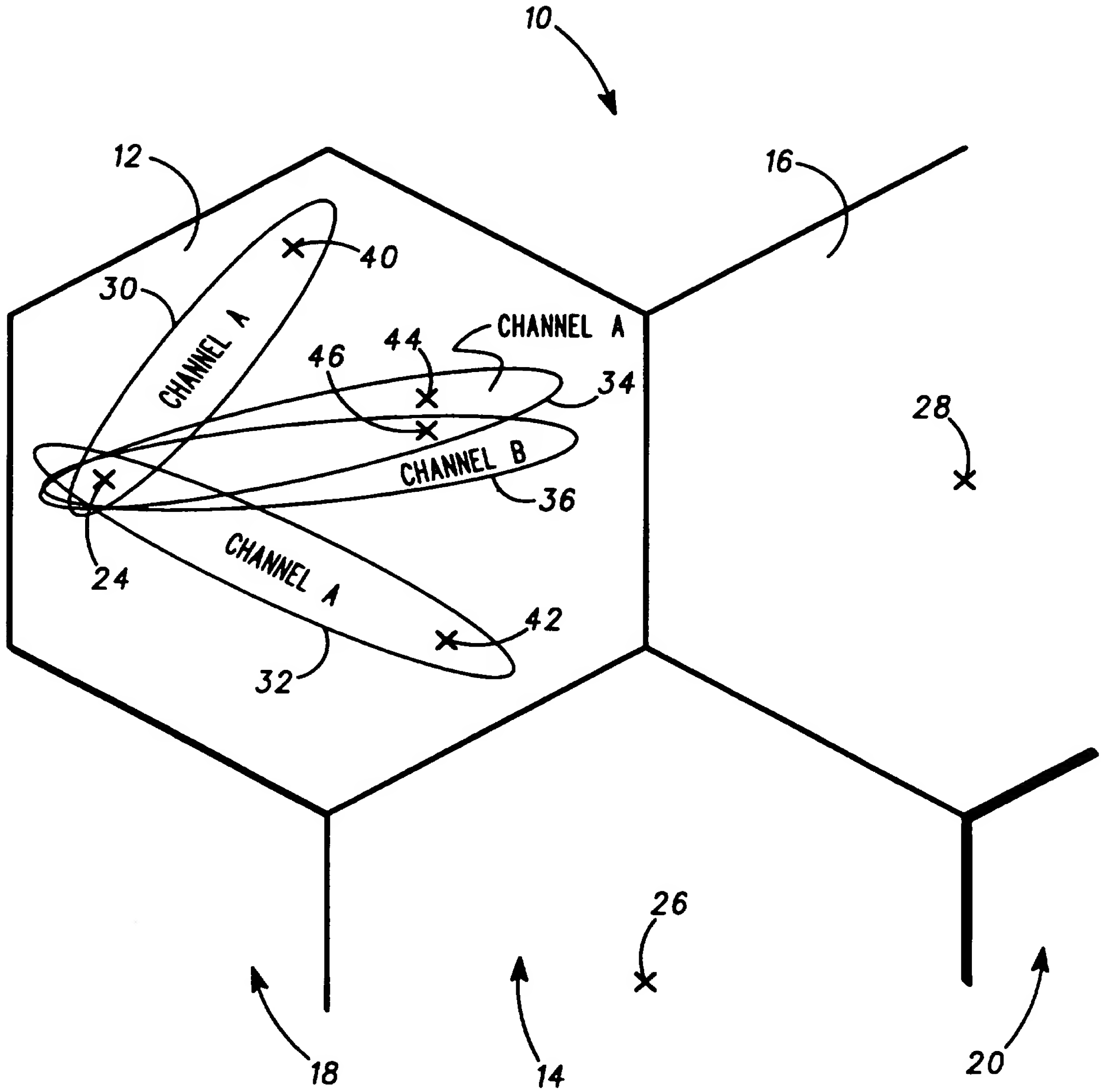
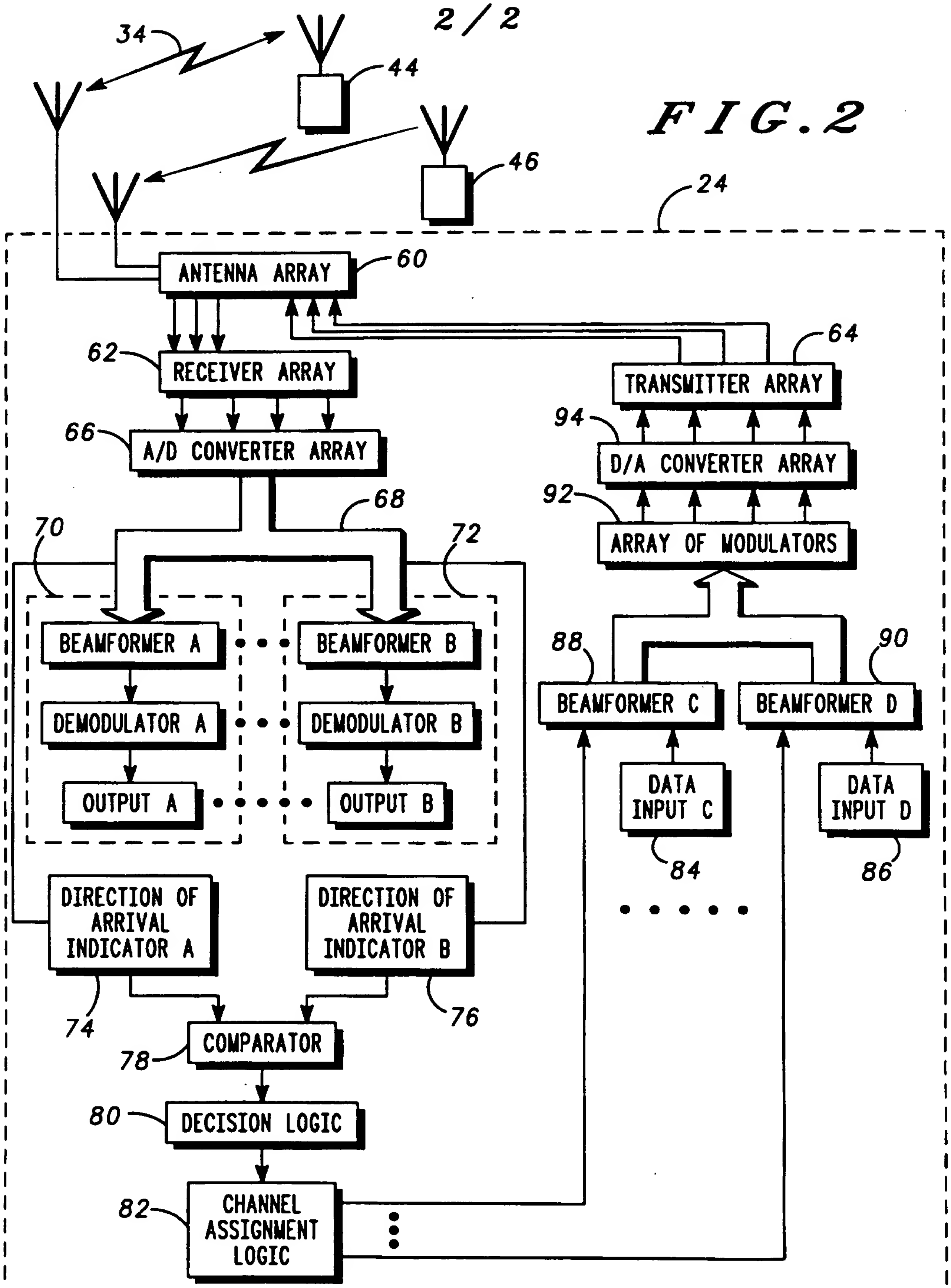

10
12
16
40
30
CHANNEL A
44
CHANNEL A
46
34
28
CHANNEL B
36
24
CHANNEL A
42
32
26
18
14
20

FIG.1

FIG.2


34
44
46
24
ANTENNA ARRAY
60
62
RECEIVER ARRAY
64
TRANSMITTER ARRAY
66
A/D CONVERTER ARRAY
94
D/A CONVERTER ARRAY
68
92
ARRAY OF MODULATORS
70
72
BEAMFORMER A
BEAMFORMER B
DEMODULATOR A
DEMODULATOR B
OUTPUT A
OUTPUT B
88
90
BEAMFORMER C
BEAMFORMER D
DATA INPUT C
DATA INPUT D
84
86
DIRECTION OF ARRIVAL INDICATOR A
DIRECTION OF ARRIVAL INDICATOR B
74
76
COMPARATOR
78
80
DECISION LOGIC
82
CHANNEL ASSIGNMENT LOGIC

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APPARATUS AND METHOD FOR CHANNEL ALLOCATION

Background of the Invention

This invention relates, in general, to communication systems and is particularly applicable to channel allocation in communication systems using an adaptive beamforming technique.

Summary of the Prior Art

The use of adaptive antennas (AA) in communication systems (particularly frequency division multiplexed (FDM) systems, such as the pan-European digital cellular Global System for Mobile (GSM) communication and alternate code-division multiple access (CDMA) systems) is becoming increasingly attractive because such adaptive antennas offer general improvements in system performance, and especially handling (traffic) capacity. As will be appreciated, a high degree of beam accuracy is achieved in an adaptive antenna system by accurately varying the phase and amplitude (magnitude) components of a transmitted wave. More specifically, phases and magnitudes of a set of transmitted waves, emanating from an array of antenna elements of a transceiver, are varied by "weighting" individual elements in the array such that an antenna radiation pattern (of a base site, for example) is adapted (optimised) to match prevailing signal and interference environments of a related coverage area, such as a cell.

Furthermore, with only a limited radio spectrum available for such communication systems, it has become imperative to optimise any allocation of channel resources between coverage areas, whilst ensuring that co-channel interference (caused by the repeated use of a single frequency in a limited area) is kept at an acceptable level (suitable for maintaining the integrity of a communication).

Summary of the Invention

According to a first aspect of the present invention there is provided apparatus for coupling to an adaptive array of antenna elements and arranged to allocate a plurality of communication resources amongst a plurality of communication units in a coverage area, comprising: means for determining a spatial resolvability of the plurality of communication units with respect to the adaptive array of antenna elements; means for assigning a first communication resource to the plurality of communication units when the plurality of communication units are spatially resolvable by the adaptive array and for dynamically assigning differing communication resources from the plurality of communication resources to the plurality of communication units when the plurality of communication units are not spatially resolvable by the adaptive array.

In a preferred embodiment the means for assigning is arranged to limit co-channel interference to a minimum and therefore to maximise spatial separation of co-channel communication units.

In an alternate embodiment the means for assigning is arranged to optimise channel resource assignment in a coverage area to an extent whereby co-channel interference approaches a level that would result in a disruption of communication.

In a second aspect of the present invention there is provided a method of allocating a plurality of communication resources amongst a plurality of communication units in a coverage area served by an adaptive array of antenna elements, comprising the steps of: determining a spatial resolvability of the plurality of communication units with respect to the adaptive array of antenna elements; and assigning a first communication resource to the plurality of communication units when the plurality of communication units are spatially resolvable by the adaptive array; and dynamically assigning differing communication resources from the plurality of communication resources to the plurality of communication units when the plurality of communication units are not spatially resolvable by the adaptive array.

An exemplary embodiment of the present invention will now be described with reference to the accompanying drawings.

Brief Description of the Drawings

FIG. 1 illustrates channel assignment and resolution between mobile units according to a preferred embodiment of the present invention.

FIG. 2 shows a block diagram of a base station constructed in accordance with the preferred embodiment of the present invention.

Detailed Description of a Preferred Embodiment

The present invention has an ability to allow optimisation of channel resource allocation in a coverage area to an extent whereby co-channel interference approaches a level that would result in a disruption of communication (either voice or data), although the present invention is preferably arranged to limit co-channel interference to a minimum (and therefore maximise spatial separation of co-channel communication units). In fact, the present invention utilises the transmission and reception properties of an adaptive (antenna) array to implement a space division multiple access (SDMA) system, in which a specific communication resource (e.g. a channel, such as a TDM radio channel, having a particular frequency and time-slot) can be re-used in a coverage area of a single base station provided that communication units served by this specific communication resource are spatially resolvable by the adaptive array. More specifically, weighting factors (beamforming coefficients) are strictly controlled by the base station such that beam patterns (i.e. the radiating lobes) for each channel from the adaptive array are both narrow and directed principally towards a particular communication unit. Indeed, down-link weights for transmissions by the base station are determined in response to weights applied to up-link communications emanating from the communication unit.

When a communication unit attempts to establish communication (i.e. register) with a base station on a random access channel (RACH), the base station estimates a relative position of the communication unit to the

base station. In the preferred embodiment, this relative position is determined by an angular measurement derived from the adaptive array. For example, angular position of the communication unit relative to the fixed adaptive array may be determined by the so-called 'MUSIC' algorithm that estimates an angle of reception (incidence) based on Eigen-value deposition of a received signal, as will be understood by the skilled addressee. Alternatively, the so-called 'ESPRIT' algorithm is used to resolve angular differences based on an estimation of signal parameters using rotational invariance techniques, as will also be appreciated by the skilled addressee. Provided that the angular measurement does not detrimentally coincide with that for another communication unit already in communication with the base station, identical channels may be allocated. To put this another way, in the event that two communication units cannot be resolved from each other in a given direction, only one of these two communication units is assigned the specific communication resource.

As will be appreciated, the angle of resolution of the adaptive array of the base station is determined by the aperture array of each antenna element thereof. Explicitly, the resolvable angle is inversely proportional to the width of the array.

The concept of the present invention can be further appreciated with reference to FIG. 1, in which channel assignment and resolution between (resolvability of) communication units (according to a preferred embodiment of the present invention) is shown. Particularly, a communication system 10, generally depicted by a plurality of coverage areas 12-20, has a base station 24-28 appropriately located in each coverage area. Each base station 24-28 serves a plurality of communication units that reside within its range (i.e. principally within the confines of its coverage area). The communication units may include mobile units that can freely roam throughout the communication system 10.

For the sake of brevity and clarity, only coverage area 12 will be discussed in detail, although the function of its base station 24 and its operation is widely applicable to the communication system 10. Now, considering coverage area 12 in detail, the base station has an ability to generate a

multitude of beams 30-36 (through the selection of different beamforming coefficients) from its associated adaptive array of antenna elements. In this respect, each beam 30-36 (shown in simplified form as an elongated ellipse) represents a communication resource (or channel). Currently, four communication devices 40-46 reside within the coverage area 12. If we consider communication device 40, which may be a cellular phone, this communication device 40 is already in communication with base station 24 and has therefore been assigned channel A on beam 30. Communication device 42 is, similarly, already in communication with base station 24, and has also been assigned channel A (but on beam 32) since the base station 24 has determined that the spatial separation between communication devices 40 and 42 is sufficient to sustain non-interfering co-channel use. Furthermore, communication device 44, which may be a portable modem, is additionally in communication with base station 24, and has also been assigned channel A (but on beam 34) since the base station 24 has determined that the spatial separation between communication devices 40, 42 and 44 is sufficient to sustain co-channel use without adverse and detrimental effect. Communication device 46 has just attempted to register with base station 24 on a RACH. However, base station 24 has determined that it either cannot resolve communication device 46 from communication device 44 on a single channel, or a spatial separation between communication devices 44 and 46 is insufficient to sustain co-channel use without adverse and detrimental effect to the integrity of both communications (since co-channel interference would potentially exceed a predetermined level deemed sufficient to cause concern). Therefore, base station 24 assigns channel B (i.e. beam 36) to communication device 46.

The adaptive array is arranged (ideally) to provide a 360° resolution from each antenna element (so as to resolve communication units in opposing directions relative to the base station), although a plurality of elements may be arranged, for example, along sides of a triangular array configuration, whereby each side of the adaptive array provides at least a 120° coverage pattern.

FIG. 2 shows, principally, a block diagram of a base station 24 constructed in accordance with the preferred embodiment of the present invention. The

base station 24 is currently in communication with communication unit 44 over channel A (provided on beam 34), whereas communication unit 46 is attempting to register with the base station 24, as previously described in relation to FIG. 1.

The base station 24 comprises an array of antenna elements 60 for receiving and transmitting multiple signals to the communication units 44 and 46. An array of antenna switches (not shown) selectively couples the array of antenna elements 60 to either an array of receivers 62 or an array of transmitters 64. Both the array of receivers 62 and the array of transmitters 64 contain a number of individual receivers and transmitters, respectively, corresponding to a number of antenna elements in the antenna array 60.

Considering a receiver path for the base station 24, each signal received by each individual antenna element is processed by a dedicated receiver, with each output from each dedicated receiver fed through a separate analog-to-digital (A/D) converter of an array of A/D converters 66. A digital signal 68 that is output from the array of A/D converters is applied to discrete, communication unit-dedicated circuits 70 and 72 comprising a beamformer, a demodulator and an output (such as a visual display unit or speech decoder). The base station 24 comprises many communication unit-dedicated circuits 70 and 72 (as will be understood), albeit that only two such circuits have been illustrated for the purposes of explanation. These communication unit-dedicated circuits 70 and 72 are responsible for forming "weights" for each received path and for decoding and displaying (or relaying) information transmitted to the base station 24 from the multitude of communication units served by the base station 24.

The digital signal 68 for each communication unit 44 and 46 served by the base station 24 is also supplied directly to dedicated direction of arrival indicator circuits 74 and 76 (specific to each communication unit). The direction of arrival indicator circuits 74 and 76 determine a relative position (spatial separation) between the communication units by applying techniques such as 'MUSIC' and 'ESPRIT'. A Comparator 78 is responsive to outputs from these direction of arrival indicator circuits 74 and 76, and decision logic 80 then determines whether communication

units 44 and 46 are resolvable on a single channel, or whether a spatial separation between communication devices 44 and 46 is sufficient to sustain co-channel use without adverse and detrimental effect to the integrity of both communications. Subject to an outcome of the comparison of the outputs from the direction of arrival indicator circuits 74 and 76, channel assignment logic 82 (responsive to decision logic 80) selects a suitable channel assignment for all the communication units served by the base station 24. The channel assignment logic is therefore somewhat indicative of a start of a transmit path for the base station 24.

In the transmit path, data inputs 84 and 86 (supplying information to be transmitted to communication units served by the base station 24) are applied, respectively, to individual beamformers 88 and 90, which beamformers 88 and 90 are responsive to channel assignment logic 82. Outputs signals from each beamformer 88 and 90 are then applied in series, as will be understood, to an array of modulators 92, an array of digital-to-analog (D/A) converters 94 and then to the array of transmitters 64 (for ultimate coupling to the array of antenna elements 60). Both the array of modulators 92 and the array of D/A converters 94 contain a number of individual modulators and D/A converters, respectively, corresponding to a number of antenna elements in the antenna array 60. Again, it will again be understood that separate beamformers are provided for each communication unit served by the base station 24.

It will, of course, be understood that the above description has been given by way of example only and that modification in detail may be made with the scope of the present invention. For example, in an alternate embodiment of the present invention, the adaptive array of the base station may also contain vertically separated antenna elements arranged to determine an angle of elevation between a communication unit and a base station. In this instance, communication units may also be separated by distance from the base station (through use of appropriate weighting factors (or 'beamforming coefficients') in addition to the azimuthal separation provided by the horizontally separated elements envisaged in the preferred embodiment of the present invention. Consequently, position information provided by virtue of this extra distance indicator can be used to maintain a geographic definition of a coverage area (i.e. to restrict a

transit range from the base station to the boundaries of its cell), such as to suppress co-channel interference between adjacent cells.

It is further contemplated that the distance measure provided by the inclusion of the angular elevation may be utilised on a system level (by an operation and maintenance centre (OMC), or the like, responsible for overall control of the base stations in the communication system) for communication resource allocation and traffic distribution. More explicitly, if an angular elevation indicates that a first communication unit is sufficiently close to a first base station of a first cell, that first base station may regulate the beamforming coefficients applied to a beam for a particular channel serving that communication device in order to restrict a range for that beam within that first cell. A second communication unit, located behind the first communication unit and towards a periphery of the first cell (i.e. at a greater distance from the first base station but at a substantially similar azimuthal angle), may therefore be served by the same particular channel if a second base station in an adjacent cell extends its range either by increasing its power output or by modifying the beamforming coefficients to be applied by the second base station to a beam for that same particular channel. However, since transmission of the same particular channel on converging beam patterns from different base stations potentially gives rise to co-channel interference, it will be understood that strict power control must be exercised by any system management centre (e.g. an OMC) to prevent unacceptable call (communication) degradation.

As such, a distance measure may also provide the system, generally, with information capable of supporting a power control regime and an ability to distribute system (user) loading between base stations (thereby providing a mechanism for both alleviating cell over-loading and optimising available channel resources). Indeed, with each base station providing position information (relating to communication units) to the system controller, the system can adapt itself to utilise overlapping beam patterns (administered from different base stations) for the same channel provided that a communication unit served by such a channel is not in an intersecting (overlapping) area of the beam patterns.

Additionally, it will be appreciated that upon initialisation of a new downlink from the master station (base station) to a fixed communication unit, co-channel assignment according to the concepts of the present invention may be employed provided that (having regard to existing channel assignments and the beamforming coefficients applied to such existing channel assignments through a comparative or projective technique) beamforming coefficients applied to the new downlink do not produce an antenna radiation pattern for the new downlink that excessively impinges on (interferes with) existing downlink channel assignments.

As such, the present invention advantageously provides a communication system that optimises channel assignment (and potentially minimises co-channel interference in a coverage area), while also allowing dynamic assignment of available channel resources upon receipt of any (or all) registration requests made by a communication unit on a RACH, or the like).

Claims

1. Apparatus for coupling to an adaptive array of antenna elements and arranged to allocate a plurality of communication resources amongst a plurality of communication units in a coverage area, comprising:

means for determining a spatial resolvability of the plurality of communication units with respect to the adaptive array of antenna elements; and

means for assigning a first communication resource to the plurality of communication units when the plurality of communication units are spatially resolvable by the adaptive array and for dynamically assigning differing communication resources from the plurality of communication resources to the plurality of communication units when the plurality of communication units are not spatially resolvable by the adaptive array.

2. Apparatus according to claim 1, wherein the means for assigning is arranged to limit co-channel interference to a minimum and therefore to maximise spatial separation of co-channel communication units.

3. Apparatus according to claim 1, wherein the means for assigning is arranged to optimise channel resource assignment in a coverage area to an extent whereby co-channel interference approaches a level that would result in a disruption of communication.

4. Apparatus according to claim 1, 2 or 3, wherein the means for assigning is arranged to dynamically assign communication resources in response to the means for determining periodically determining a spatial resolvability between the plurality of communication units.

5. Apparatus according to any preceding claim, wherein the communication resource is a radio channel.

6. Apparatus according to claim 5, wherein the channel is a particular frequency and time-slot.

7. Apparatus according to any preceding claim, wherein the means for assigning comprises means for selecting different beamforming coefficients.

8. Apparatus according to any preceding claim, wherein the means for determining is responsive to an azimuthal angle obtained from a signal received by the adaptive array of antenna elements.

9. Apparatus according to claim 8, wherein the means for determining is further responsive to an elevational angle obtained from a signal received by the adaptive array of antenna elements.

10. Apparatus according to claim 9, further comprising:

control means for regulating a range of a beam for a channel resource in response to a position indication of a communication unit derived from the azimuthal angle and the elevational angle.

11. Apparatus according to any preceding claim, wherein the apparatus is a base station.

12. A method of allocating a plurality of communication resources amongst a plurality of communication units in a coverage area served by an adaptive array of antenna elements, comprising the steps of:

determining a spatial resolvability of the plurality of communication units with respect to the adaptive array of antenna elements; and

assigning a first communication resource to the plurality of communication units when the plurality of communication units are spatially resolvable by the adaptive array; and

dynamically assigning differing communication resources from the plurality of communication resources to the plurality of communication units when the plurality of communication units are not spatially resolvable by the adaptive array.

13. The method of allocating according to claim 12, wherein the step of dynamically assigning is arranged to limit co-channel interference to a minimum and therefore to maximise spatial separation of co-channel communication units.

14. The method of allocating according to claim 12, wherein the step of dynamically assigning is arranged to optimise channel resource assignment in a coverage area to an extent whereby co-channel interference approaches a level that would result in a disruption of communication.

15. Apparatus for coupling to an adaptive array of antenna elements and arranged to allocate a plurality of communication resources amongst a plurality of communication units substantially as hereinbefore described with reference to the accompanying drawings.

16. A method of allocating a plurality of communication resources amongst a plurality of communication units in a coverage area served by an adaptive array of antenna elements substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

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Application No:	GB 9601951.8	**Examiner:**	Nigel Hall
Claims searched:	ALL	**Date of search:**	22 March 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4L (LDSE, LDSG, LDSH, LDSJ, LDSL)

Int Cl (Ed.6): H04Q 7/36, 7/38

Other: ONLINE: WPI, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	WO96/00484 A1 (ERICSSON) whole document	1,12
X	Zetterberg, P and Ottersten, B, "The Spectrum Efficiency of a Base Station Antenna Array System for Spatially Selective Transmission", IEEE Transactions on Vehicular Technology, vol. 44, no. 3, August 1995, pp. 655-656	1,12
X	Gerlich, N and Tangemann, N, "Towards a Channel Allocation Scheme for SDMA-based Mobile Communication Systems", ITG-Fachberichte Conference Title: ITG-Fachber. (Germany) no. 135, 1995, VDE-Verlag, pp. 110-111	1,12

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.